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UK CL (Edition M) H2A
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(54) Electromagnetic transmission system including variable-speed electric motor

(57) An electromagnetic transmission system comprises an input rotor (1), arranged concentrically with an output rotor (2) within a casing (3). Drive supplied to the input rotor (1) is transmitted to the output rotor (2) and current supplied to windings of the casing (3) is used to control output rotor speed independently of input rotor speed. The current may be supplied externally or from the input rotor acting with the output rotor to form a generator due to the slip. As shown in Figure 4 electromagnets on part 21 of the input rotor connected to windings on part 20 may be used to apply current directly to the section 24 of the casing carrying first windings, second winding on part 25 acting on the second rotor the current direction between these parts may be switched to reverse the output rotor. Alternatively brushes 6, Fig. 2, may extract the power to supply the casing winding or charge a battery. Lock up may be provided and a free wheel system may prevent overrun of the output rotor. Vehicle applications are disclosed.

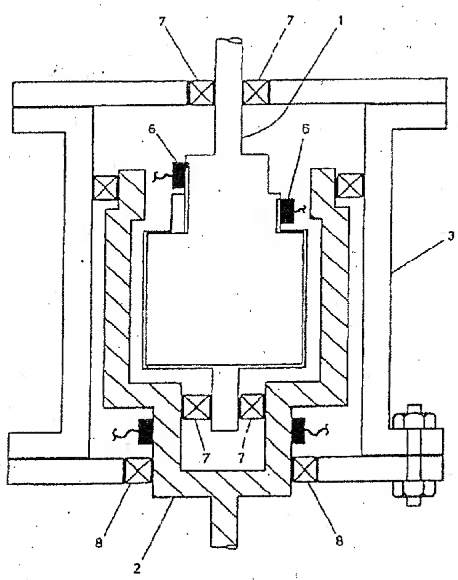

FIG. 2

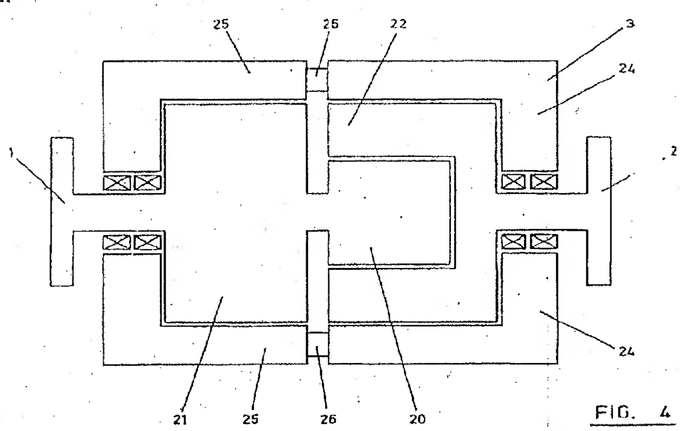

FIG. 4

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patents Rules 1990.

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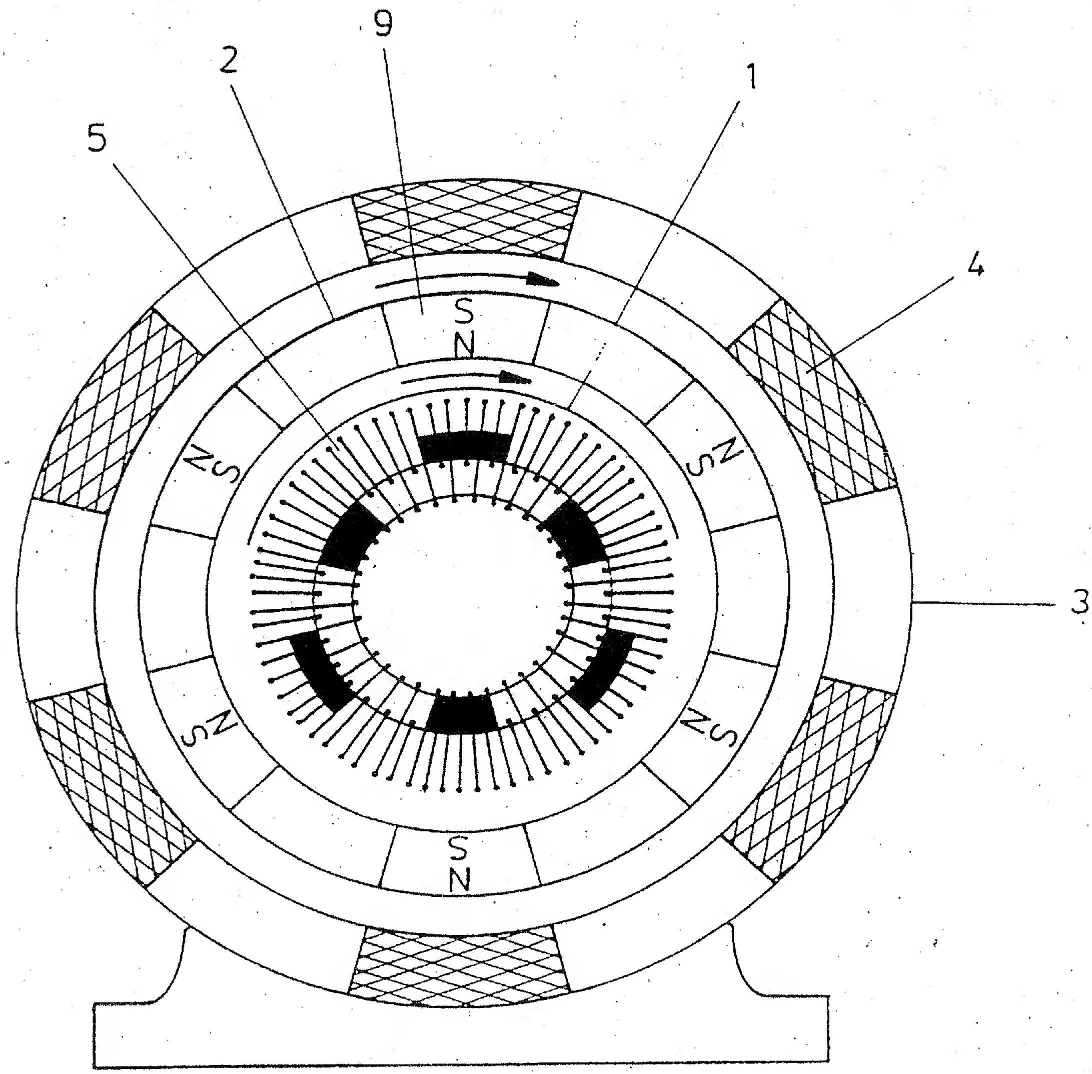


FIG. 1

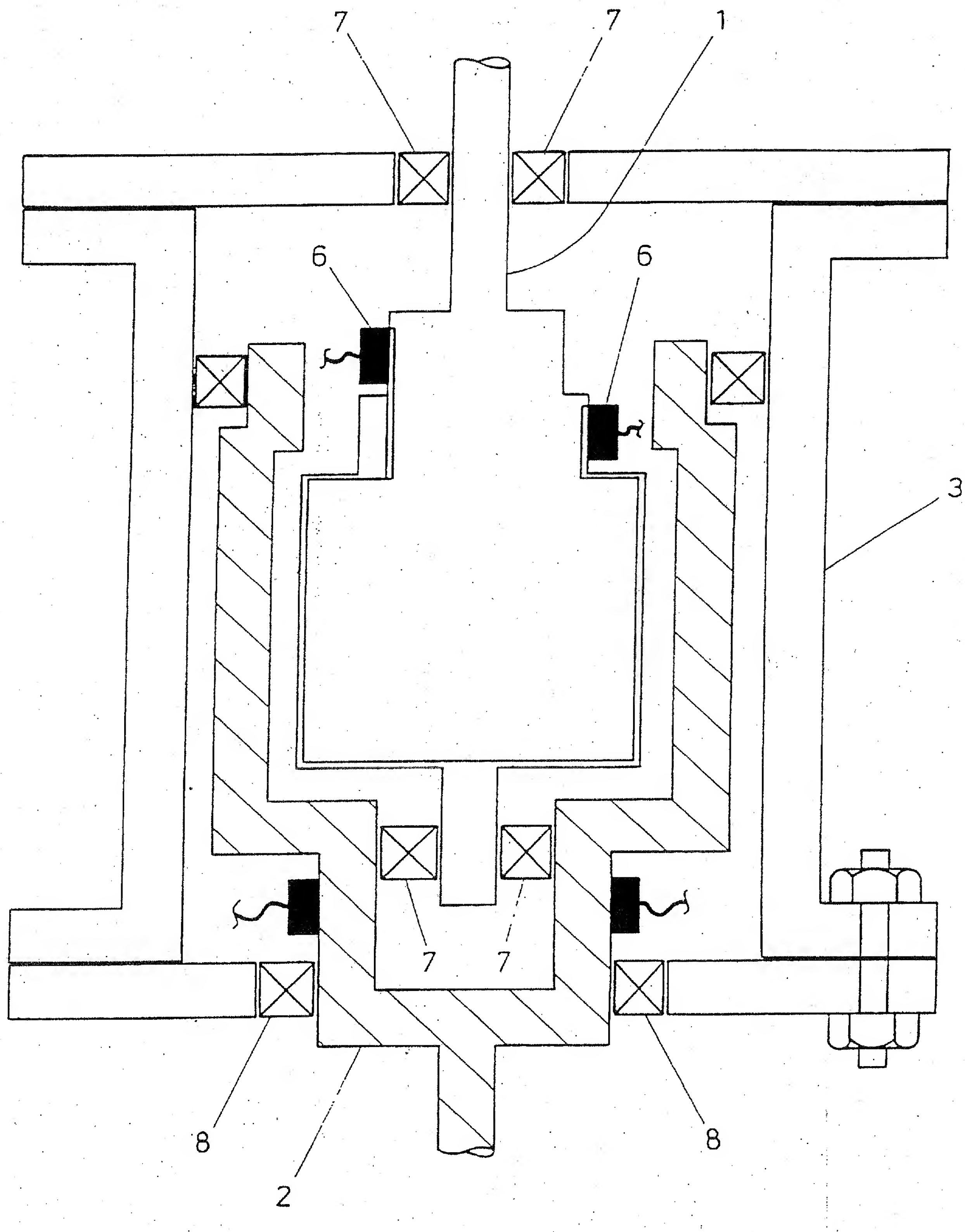


FIG. 2

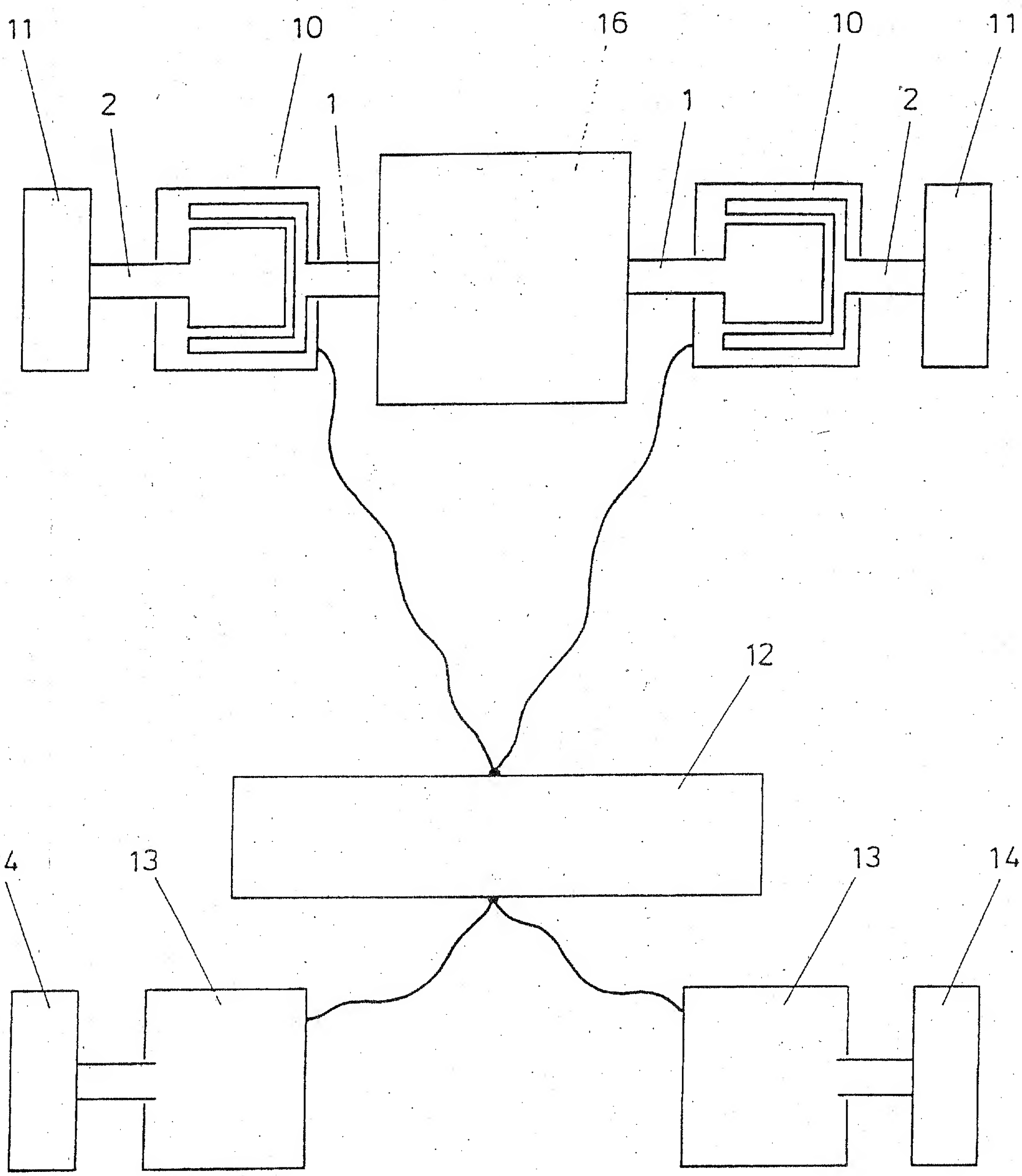


FIG. 3

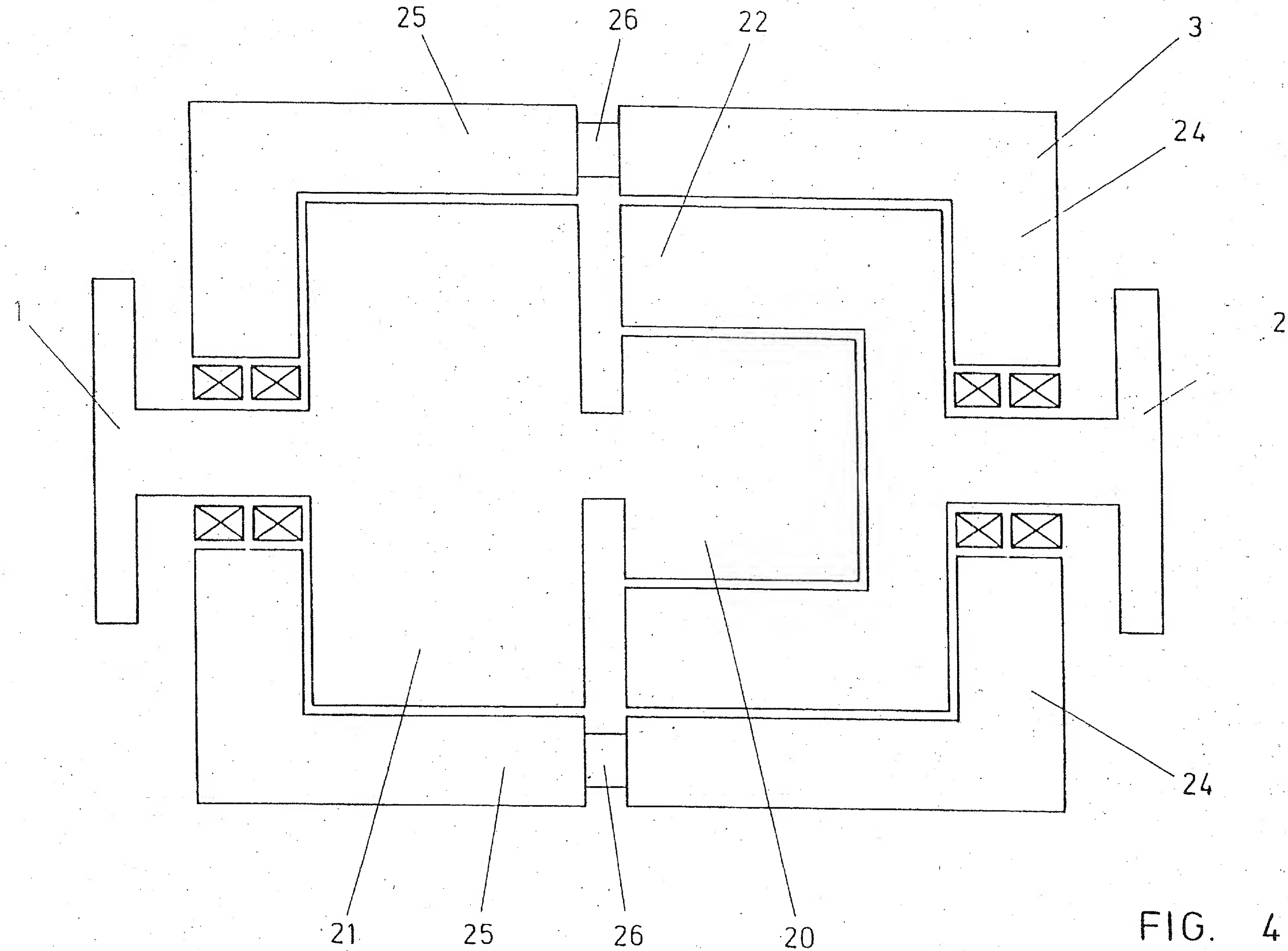


FIG. 4

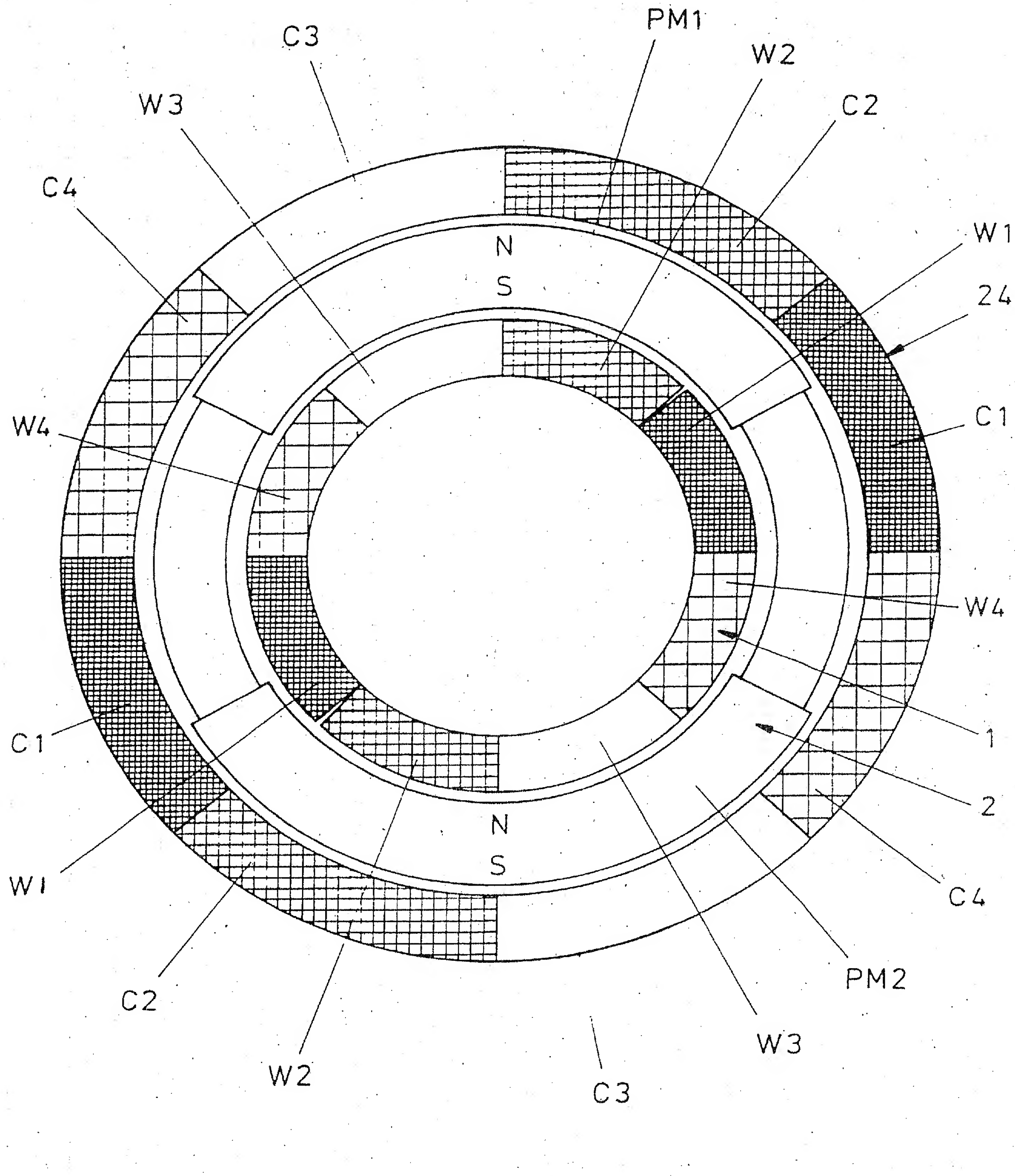


FIG. 5

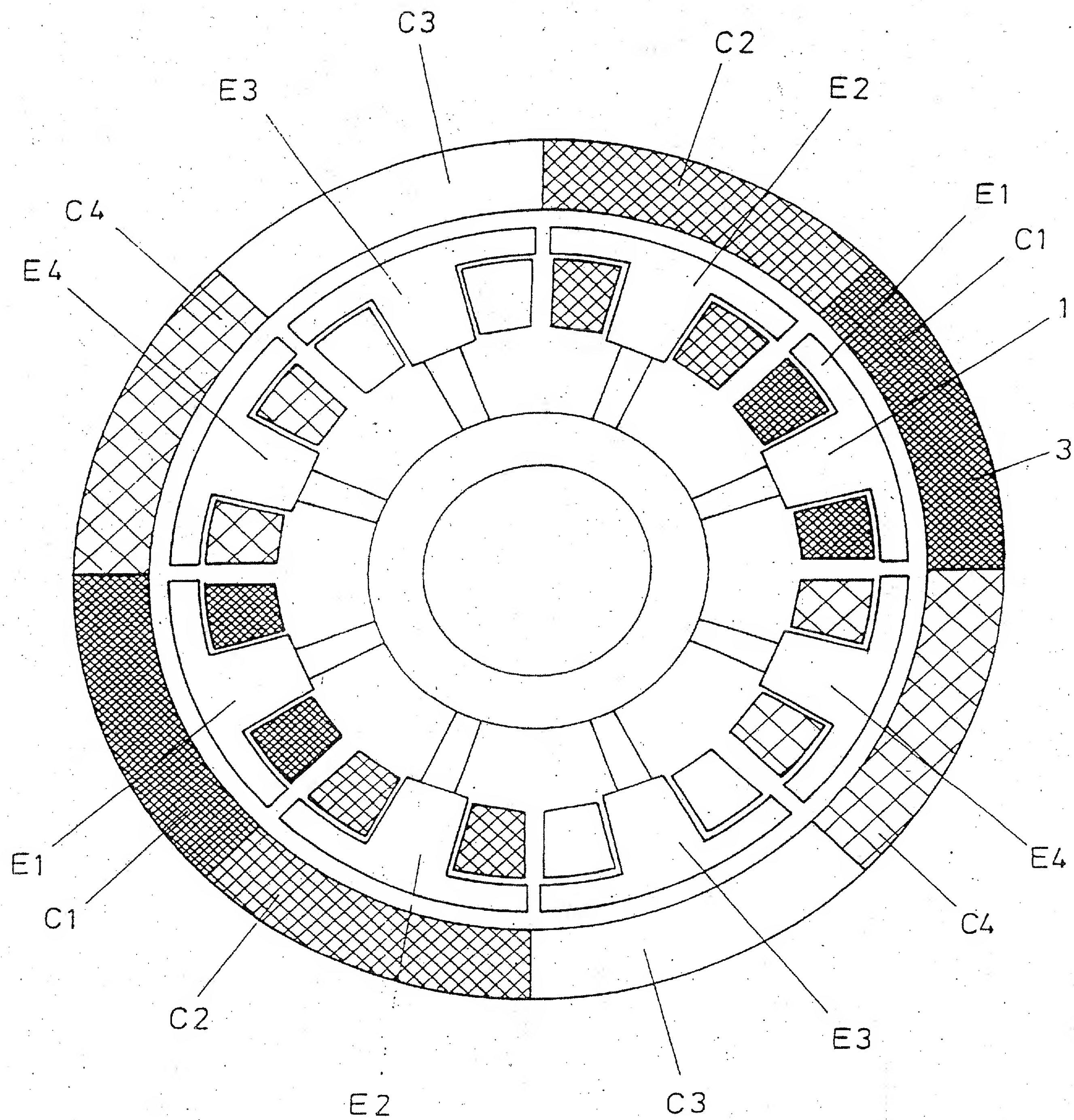


FIG. 6

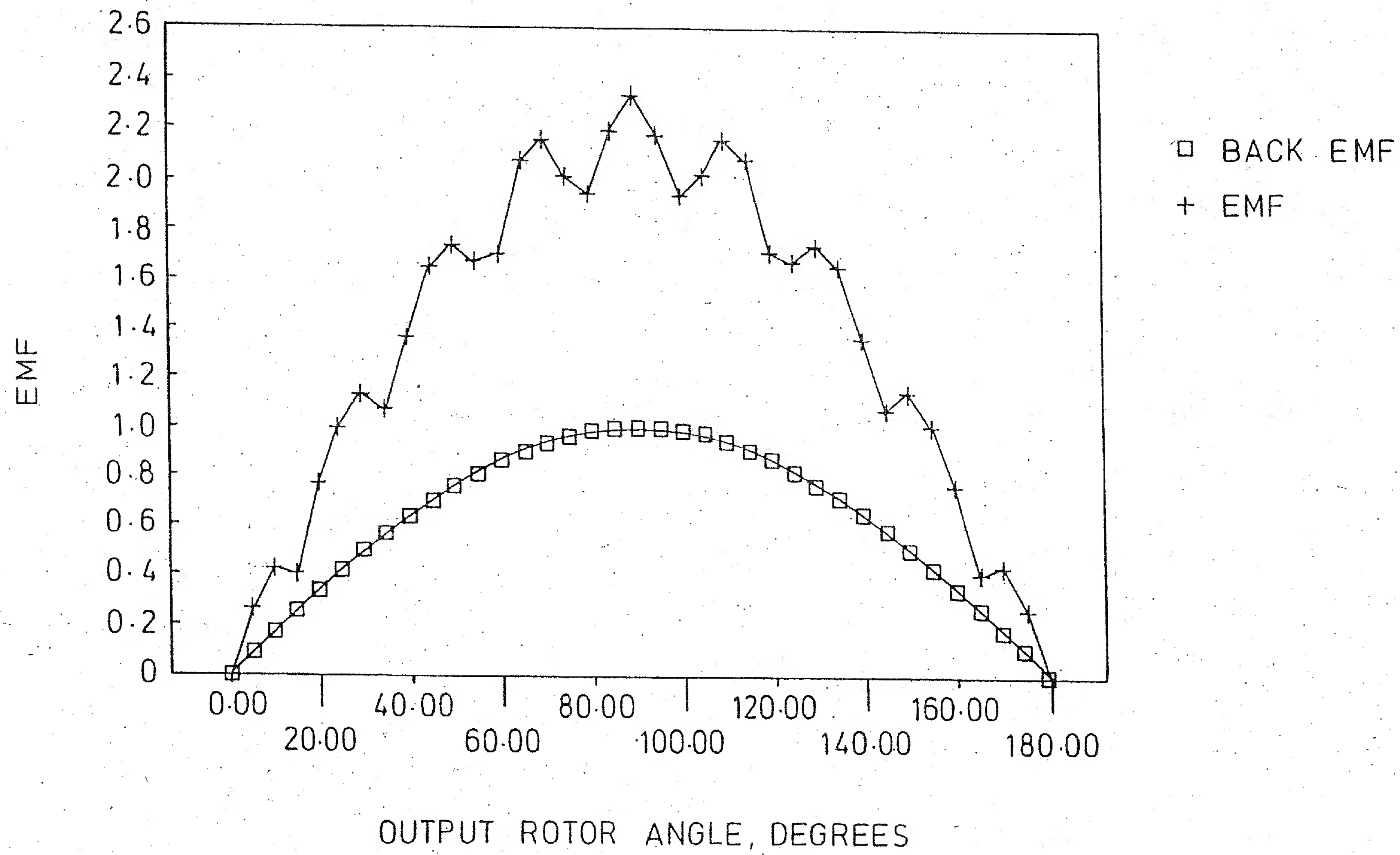
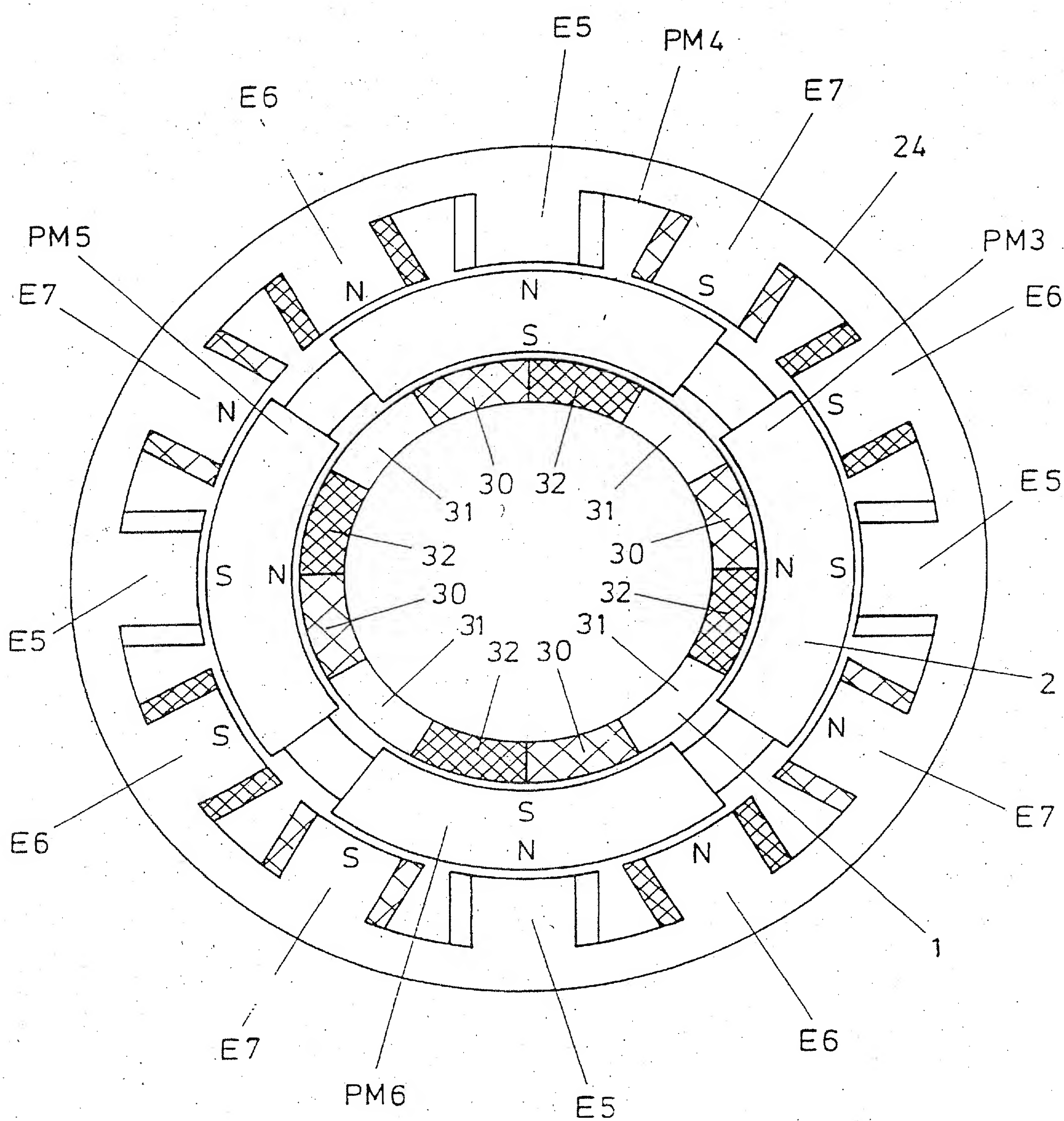

EMF
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
OUTPUT ROTOR ANGLE, DEGREES
□ BACK EMF
+ EMF

FIG. 7


E5
PM4
E6
E7
24
PM5
PM3
E7
E6
N
N
S
N
S
N
S
S
E5
30
32
31
31
32
30
S
N
N
S
30
32
E5
31
31
32
30
2
S
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E6
E7
S
S
N
N
E6
1
E7
E6
PM6
E5

FIG. 8

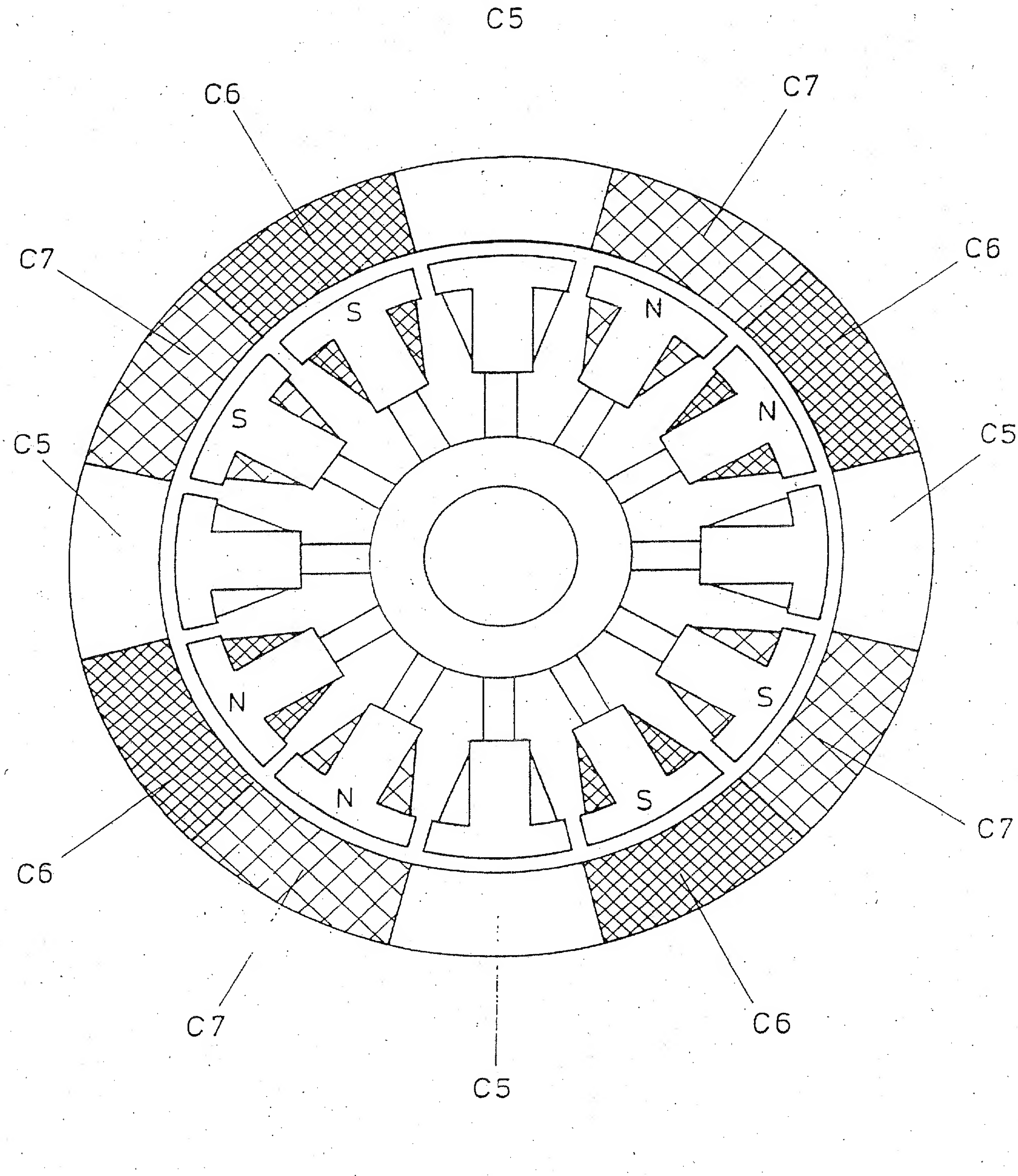

FIG. 9

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ELECTROMAGNETIC TRANSMISSION SYSTEM

The invention relates to an electromagnetic transmission system.

Road vehicles require a form of transmission which would provide different overall ratios and tractive effort to suit conditions ranging from climbing steep gradients or accelerating to a maximum driving speed on level ground. Ideally this would be accomplished by a form of infinitely variable transmission, giving a first gear ratio upon starting and progressively altering the ratio during operation.

Five-speed manual gearboxes and four-speed automatic gearboxes are nowadays quite common for passenger cars and up to sixteen gears may be employed for trucks. The trend toward providing more gears over recent years is an attempt to enable the engine to operate at its most economical speed over a wide range of road conditions.

An alternative to such manual gearboxes which is closer to the ideal of an infinitely variable transmission is provided by electrical and hydrostatic transmissions. Such transmissions consist of an electrical generator (or hydraulic pump) coupled to the engine and electric motors (or hydraulic motors) at the driving wheels. However, these types of transmission suffer from being relatively large in size and have a low overall efficiency.

Another area in which some form of speed controlling device or transmission is desirable is in the field of cooling fans. Controlling the speed of a cooling fan for a road vehicle is desirable because when the road vehicle is travelling at high speed there is often enough cooling effect without using

a fan at all. However, at such high road speeds cooling fans which are driven by the crank shaft of an engine are in fact rotating at a high speed. Conversely, when the car is stationary in traffic the engine will merely be idling and the fan will be moving at a low speed, just at the point at which the fan is needed most.

To improve efficiency and reduce noise with cooling fans a viscous coupling is sometimes used which has the ability to increase the speed of the fan when the temperature of the air exiting the radiator increases. This speed control is not very precise however and energy dissipated from the device is given out in the form of heat.

A first aspect of the invention provides an electromagnetic transmission system having electric and magnetic circuits and comprising an input rotor, and an output rotor mounted concentrically with respect to the input rotor, wherein rotation of the input rotor at a given input rotor speed causes a corresponding rotation of the output rotor at an output rotor speed equivalent to the input rotor speed minus a slip speed.

Preferably, the rotational speed of the output rotor is controllable independently of the input rotor's speed.

Preferably, the transmission comprises a casing adjacent the rotors. Suitably, the casing surrounds the input and output rotors, and is concentric with the input and output rotors, although the casing may be a static member arranged co-axially of the input and/or output rotor(s), the input and output rotors being arranged to revolve around the casing.

Preferably, the casing is provided with a number of windings and output rotor speed is controllable by supplying an electrical current to the casing windings.

Preferably, the input rotor is provided with electrical contacts such that an electrical current which is induced in the input rotor by relative rotation of the input and output rotors and which is dependent upon the slip speed can be extracted from the input rotor. Alternatively, this current extraction may be by induction.

Electrical current induced in the input rotor by relative rotation of the input and output rotors may be used to energise input rotor electromagnets located on the input rotor. These input rotor electromagnets may be configurable to generate an electrical current in the casing windings by the motion of the input rotor within the casing.

Preferably, input rotor windings are provided on a first part of the input rotor and the input rotor electromagnets are provided on a second part of the input rotor.

Preferably, switches are provided between the input rotor windings and the input rotor electromagnets to enable the polarity of the input rotor electromagnets to be changed.

Preferably, the casing is formed in first and second parts and windings are provided on both parts of the casing. Switches may be provided linking casing windings of the first and second parts, so that the current flowing in windings of the second part may flow in either the same direction or the

opposite direction to that of current in windings of the first part in accordance with a status of the switches.

Preferably, the first part surrounds the input rotor electromagnets and the second part surrounds the output rotor.

Preferably, angular positioning of the first and second parts of the casing relative to one another is adjustable.

Preferably, the first and second parts are linked together by resilient biasing means and angular adjustment is provided automatically. This automatic adjustment utilises the torque reaction of the input rotor against the resilient biasing means linking the first and second parts. In this manner, as input rotor speed increases, an automatic compensation for "armature reaction" is provided. Alteratively, such adjustment may be provided manually. The adjustment may be locked into position.

Preferably, the current induced in the input rotor is provided to the casing windings. Alternatively, an external power source may be provided for supplying some or all of the current required by the casing windings and all or part of the current induced in the input rotor may be used for other purposes, such as for re-charging a battery or other energy storage device or powering electrical accessories.

Alternatively all or part of the current induced in the casing may be used for other purposes, such as for recharging a battery or other energy storage device or for powering electrical accessories.

Preferably, the input rotor and casing are each provided with a number of phase windings.

Preferably, three-phase windings are provided.

The output rotor may comprise one or more output rotor electro-magnets.

The output rotor electro-magnets may be supplied with current by an external power source or with current extracted from the input rotor.

Preferably, the electrical current supplied to the output rotor electromagnets is controllable.

Preferably, the frameworks of the input rotor, output rotor and casing contain magnetic material to provide magnetic circuits.

In a first alternative, the output rotor may comprise one or more permanent magnets.

In a second alternative, the output rotor may comprise one or more salient poles of soft magnetic material. In this case, a controllable external power source may be supplied to the windings of the input rotor or casing.

A further aspect of the invention provides an infinitely variable automatic transmission for a vehicle utilising the electro-magnetic transmission system of the first aspect of the invention. Such a transmission may be used

on road or off-road vehicles including such vehicles as bicycles or human/electric powered vehicles.

Preferably, the infinitely variable transmission is provided between a vehicle motor and one or more wheels.

Each wheel of the vehicle may be provided with its own infinitely variable transmission unit. Alternatively, a single infinitely variable transmission unit may be utilised for driving either the front wheels or the rear wheels of the vehicle.

Preferably, a lock-up device is provided for use at cruising speeds.

Preferably, a free wheel device is included between the input and output rotors so that the output rotor is prohibited from going faster than the input rotor.

Drive to the input rotor from the vehicle motor may be disconnected so that the transmission may be used as an independent electrical motor for powering the vehicle.

Electrical power may be extracted from the transmission system to act as a vehicle brake. This power may be used to regenerate an energy storage device or may be dissipated as heat through a resistance.

A yet further aspect of the invention provides a fan-drive utilising the electro-magnetic transmission system of the first aspect of the invention.

Preferably, in the fan-drive a fan is connected to the output rotor and drive is connected to the input rotor.

A temperature sensor may be provided in the cooling system such that one or more windings in the output rotor and/or one or more windings in the casing are provided with an electrical current to control the speed of the fan.

Electrical power generated by rotation of the input rotor may be used to charge a battery.

Permanent magnets may be provided on the output rotor. Implementing the output rotor in such a manner provides a torque limiting device.

Another aspect of the invention provides an electrical motor comprising an input stator, an output rotor mounted concentrically with respect to the input stator, and a fixed casing surrounding the input stator and the output stator, wherein supplying electrical power to both the stator and to casing windings causes the output rotor to rotate. Such an electrical motor may be formed by inhibiting rotation of the input rotor of the transmission system according to the first aspect of the invention - so as to convert the input rotor into a stator - and supply power to the stator and to casing windings.

In this manner, the cooperative effect of causing rotation of the output rotor by supplying electrical power to both the stator and to the casing windings produces a relatively compact electrical motor.

The invention includes an electromagnetic transmission system comprising an input rotor having an input magnetic circuit, an output rotor having an output magnetic circuit and mounted concentrically with respect to the input rotor, and a casing surrounding the input and output rotors, wherein rotation of the input rotor at a given input rotor speed causes a corresponding rotation of the output rotor at an output rotor speed equivalent to input rotor speed minus a slip speed.

By way of example, specific embodiments of the present invention will now be described, with reference to the accompanying diagrammatic drawings. In which:

Figure 1 shows a cross sectional view of an electromagnetic transmission system;

Figure 2 is a schematic diagram showing the major components of the transmission system of Figure 1;

Figure 3 is a schematic diagram illustrating the layout of a transmission system when used in a hybrid electrical/internal combustion engine road vehicle;

Figure 4 shows the major components of a second embodiment of an electromagnetic transmission system;

Figure 5 shows a cross sectional view of the right hand side of the transmission of Figure 4;

Figure 6 shows a cross sectional view of the left hand side of the transmission of Figure 4;

Figure 7 shows a graph comparing the generated emf with the back emf for one winding of the transmission of Figure 4;

Figure 8 shows a cross sectional view of the right hand side of a third embodiment of an electromagnetic transmission system; and

Figure 9 shows a cross sectional view of the left hand side of the transmission of Figure 8.

Referring initially to Figures 1 and 2, the electromagnetic transmission of Figures 1 and 2 has three major components: an input rotor 1, an output rotor 2 and a casing 3.

The output rotor 2 is arranged to surround the input rotor 1 and the casing 3 surrounds the output rotor. The casing 3 is static, the input rotor 1 is free to rotate within bearings 7 at a speed determined by an input motive force and the output rotor 2 also free to rotate within bearings 8. As will be discussed later, the output rotor 2 rotates at a speed determined by the input motive force, the magnetic field created in the output rotor and the loading on the output rotor.

The input and output rotors interact so as to form a generator. The output rotor 2 forms the "generator casing", however, in the present invention the "generator casing" is free to rotate.

The input rotor has a number of windings 5 which connect to brushes 6. As the input rotor is rotated under the action of an input motive force, the output rotor 2 will also rotate, but at a speed less than the input rotor 1. In this way, torque is transmitted to the output rotor. The differential speed between the input and output rotors generates a current in the input rotor coils. This electrical power can be extracted by the brushes 6 and used elsewhere. Some or all of this power could be transmitted to the casing windings.

The casing 3 and the output rotor 2 (ignoring for a moment the effect of the input rotor) interact so as to form an electrical motor, power supplied to the casing windings 4 causing rotation of the output rotor.

In use, the "generator" and "motor" effects combine so that an input motive force to the input rotor 1 and the magnetic field created in the output rotor 2 provide a mechanical output at the output rotor 2 and an electrical output from the input rotor windings 5. This electrical output can be fed to the casing windings 4 to provide additional mechanical output at the output rotor 2.

Considering the use of the device of Figures 1 and 2 as an automatic transmission, it can be seen that as input power to the input rotor is increased the output power from the output rotor 2 will also increase. The speed of the output rotor will be determined by the input torque, input speed, magnetic field and output torque. If the input speed is kept constant (eg. by an automatic control of the engine throttle) varying output speeds can still be obtained by controlling the magnetic field in the output rotor 2.

Looking at the device from a force/reaction analysis, the torque transmitted by the "generator section" (formed by the input and output rotors) is equal and opposite. Ignoring the electricity generated by the input rotor 1 at the brushes 6, the result is a speed reducing gearbox without torque multiplication. However, if electrical power is fed to the casing a torque reaction against this casing is provided which gives additional torque to be supplied to the output rotor. In this manner, torque multiplication can be achieved in the device.

The output rotor 2 contains six pairs of magnetic poles 9 which can be either permanent magnets or electromagnets. Power for the electromagnets can be provided from batteries or other external power source and transmitted to the rotor through slip rings or induction. The resultant current in the rotor is designed to be direct current so that each pole retains a constant polarity. This current may be variable however so as to provide an extra control to increase or decrease the magnetic field intensity.

The input rotor windings 5 allow a 3-phase current to be extracted by brushes 6 provided at six positions fixed relative to the casing. The frequency of this alternating current will be dependent on the output rotor speed.

By feeding this current to windings 4 in the casing 3 at the same six relative positions the casing/output rotor combination becomes a synchronous motor.

A second example of the present invention will now be described, with reference to Figures 4 to 7 in which like elements are designated by like numerals.

The electromagnetic transmission of Figures 4, 5 and 6 has three major components, an input rotor 1, and output rotor 2 and a casing 3.

The input rotor consists of two parts, a left hand part 21 and a right hand part 20. The right hand part 20 contains four electrical windings W1-W4 and is partially enclosed by a portion 22 of the output rotor 2. The left hand part 21 contains electromagnets E1-E4 which are electrically connected to the windings W1-W4 on the right hand part 20. The left hand part 21 is situated inside the casing 3 but is not enclosed by the portion 22. A right hand part 24 of the casing surrounds the output rotor 2. The output rotor in this example comprises two permanent magnets PM1, PM2 mounted on the portion 22.

As the input rotor 1 is rotated the output rotor 2 will start to rotate at a speed slower than the input rotor 1. A current will be generated inside the input rotor windings W1-W4 of the right hand part 20 due to the differential speed between the input and output rotors. Each of the four windings on the input rotor 1 in this example is connected via a switch (not shown) to opposed pairs of electromagnets E1-E4 on the portion 21 of the input rotor 1. The electromagnets E1-E4 act as a generator on windings C1-C4 provided in the casing 3. The current generated in the casing windings C1-C4 then acts as a motor on the output rotor 2.

Comparative values of the emf developed in the casing windings C1-C4 and the back emf have been calculated on the assumption that an input rotor speed of twice the desired output rotor speed is applied and that the strength of the electromagnets E1-E4 of the portion 21 is the same as that of the permanent magnets PM1, PM2 at this differential speed. A graph of these

emf values for each 5 degree turn of the output rotor is shown in Figure 7. This graph is for one winding only. The graph for the next of the four windings will be similar but will start at 45 degrees, and so on.

The switches (not shown) on the input rotor 1 are used to enable a change in the polarity of the electromagnets E1-E4 so that the current in the windings C1-C4 of the casing 3 is reversed. The casing windings C1-C4 will then act on the output rotor 2 to provide a torque in the opposite direction to previously. This provides a reverse gear facility. In this mode of operation the input rotor 1 is applying a torque to the output rotor 2 in the opposite direction to that applied by the casing windings C1-C4. At a reasonable input speed, however, the torque generated by the casing windings C1-C4 will be the greater and therefore the direction of rotation of the output rotor 2 will be opposite to the direction of the input rotor 1.

A further feature of this example is that the left hand side 25 of the casing is spring coupled to the right hand side 24 by resilient biasing means 26 so that its orientation compared to the right hand side 24 can be varied. The torque applied by the input rotor electromagnets E1-E8 will act against this spring force and thereby change the orientation of the casing 3 as the input speed increases. This change of orientation is required to counteract "armature reaction". In the case of reversing this orientation can be locked into a best position.

Another feature is the provision of a free wheel device between the input and output rotors. This facility prohibits output speed of the rotor 2 from increasing above the input speed of the rotor 1 when coasting or braking.

A third example of the present invention will now be described, with reference to Figures 8 and 9 of the drawings.

The overall layout of the major components of this example is similar to the second example and like parts are designated by like numerals.

The output rotor 2 contains four permanent magnets PM3-PM6. The part 20 of the input rotor 1 which is inside the part 22 of the output rotor 2 contains three coils 30-32 of wire. Each wire is wound as follows: Consider twelve slots around the circumference of the rotor 1. The first wire is run along one of the slots from left to right and returns along the fourth slot. It then runs along the seventh slot returns along the tenth slot and then repeats along the first slot. The second and third wires are wound similarly commencing at the second and third slots respectively.

Each wire is connected to four electromagnets E5-E8 on the other part of the input rotor 1 which is situated inside the casing windings. The electromagnets are wired in a similar order to the windings on the input rotor inside the output rotor. The location of the first electromagnet for the first wire will be 45 degrees from the first slot.

Windings C5-C7 in the casing 3 which surround the input rotor 1 are also wound in a similar manner. Each of the three windings C5-C7 is similarly connected to three electromagnets E5-E7 provided on the right hand part 24 of the casing 3 surrounding the output rotor 2. The resulting polarities of the magnets E5-E7 for the particular position showed in the drawings are indicated. The result will be a clockwise rotation of the output rotor 2.

As in the second example a reverse gear facility is possible although the input rotor 1 will be exerting a torque in the opposite direction to the torque exerted by the casing electromagnets E5-E7. Reverse could be accomplished by turning one part of the casing 3 through 90 degrees compared with the other part of the casing. Alternatively switches could be employed between the two halves of the casing 3.

Adjustment for "armature reaction" can be accomplished as before by turning part of the casing through the required angle.

The transmission could be used as an infinitely variable automatic transmission for a road vehicle. During starting and accelerating the power transmitted directly to the output rotor will be small compared to the power converted to electricity and back to mechanical power, ie. there will be a high speed differential between the input and output rotors. During steady speed running, however, a larger proportion of the power can be transmitted directly to the output rotor thereby improving efficiency. A lock up device at an appropriate gear ratio could also be incorporated for use at cruising speeds. Throughout the majority of road conditions the device has the potential to be significantly more efficient than a conventional separate generator and motor transmission. It also has the potential to be at least as efficient as a hydro-kinetic torque converter and automatic gearbox with the added advantage of possessing infinitely variable ratios allowing the engine to be operated at its most efficient speed. It also has the potential to be built large enough to be used on trucks and may also be suitable for use with gas turbine powered vehicles.

Vehicle braking may be achieved by extracting electrical power from the system, this power can be used to regenerate an energy storage device, for instances. The reverse gear facility may also be advantageously applied to provide electrical braking.

A free wheeling device may be utilised to prevent output rotor speed from increasing above input rotor speed.

The transmission could also be used as a fan drive on a car or truck engine cooling fan. A temperature sensor in the cooling system could control the current to output rotor windings and/or casing windings thereby controlling the speed of the fan. A simpler version could be considered without casing windings where the electrical power generated is either used to charge a battery or is fed to a resistance to be dissipated as heat. An even simpler version could use permanent magnets on the output rotor with the result that it becomes a torque limiting device suitable for cars where the cooling fan is not required at high engine and road speeds.

A version using a casing without windings could also be used on an electric/internal combustion engine hybrid vehicle for direct drive to one wheel and use an electric motor on another wheel. On the example shown in Figure 3, exemplary electromagnetic transmissions 10 are used to drive the front wheels 11 from internal combustion engine 16 and generate electricity to charge a battery 12. The battery can also supply power to two electric motors 13 driving the rear wheels 14. If used on a car of average size requiring, say, a maximum power output of 70 kw, an engine of 35 kw could be combined with two 17.5 kw electric motors. In town the engine could be stopped and purely battery power used. When cruising out of town the engine

could be restarted to propel the front wheels and replenish the battery. When maximum power is required for acceleration both the engine and battery power can be used.

A further non-illustrated version of the above could use one transmission (with casing windings) attached to the engine with additional power being fed to the casing windings from the battery when required. When cruising electrical power could again be extracted to charge the battery. By disconnecting the engine from the input rotor the transmission could be used as an electric motor for in town.

It is also envisaged that a relatively compact electrical motor could be provided by reconfiguring the described systems such that the input rotor 1 is fixed. In this manner, the input rotor 1 becomes a stator.

The cooperative effects of feeding electrical power to windings on the stator and to the casing windings gives rotation of the output rotor 2. Regulation of the output rotor speed can be achieved by varying the amount of electrical power supplied to the stator and/or to the casing windings.

Other embodiments may be configured to include a central casing arranged concentrically with the input and output rotors, and co-axially with a main axis of rotation of the input and output rotors, the arrangement being that the central casing remains static, whilst the input and output rotors revolve around the casing.

The reader's attention is directed to all papers and documents which are filed concurrently with or previous to this specification in connection with this

application and which are open to public inspection with this specification, and the contents of all such papers and documents are incorporated herein by reference.

All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive.

Each feature disclosed in this specification (including any accompanying claims, abstract and drawings), may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

The invention is not restricted to the details of the foregoing embodiment(s). The invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed.

CLAIMS

1. An electromagnetic transmission system having electric and magnetic circuits and comprising an input rotor, an output rotor mounted concentrically with respect of the input rotor, and a casing, wherein rotation of the input rotor at a given input rotor speed causes a corresponding rotation of the output rotor at an output rotor speed equivalent to the input rotor speed minus a slip speed.

2. A system according to claim 1, wherein the rotational speed of the output rotor is controllable independently of the input rotor speed.

3. A system according to claim 2, wherein the casing is provided with a number of windings and the output rotor speed is controllable by supplying an electrical current to the casing windings.

4. A system according to claim 3, wherein the input rotor is provided with electrical contacts such that an electrical current which is induced in the input rotor by relative rotation of the input and output rotors and which is dependent upon the slip speed can be extracted from the input rotor.

5. A system according to claim 3 or 4, wherein an electrical current induced in the input rotor by relative rotation of input and output rotors can be extracted from the input rotor by means of induction.

6. A system according to claim 3, 4 or 5, wherein electrical current induced in the input rotor by relative rotation of input and output rotors is used to energise input rotor electromagnets located on the input rotor.

7. A system according to claim 6, wherein the input rotor electromagnets are configurable to generate an electrical current in the casing windings.

8. A system according to claim 6 or 7, wherein input rotor windings are provided on a first part of the input rotor and the input rotor electromagnets are provided on a second part of the input rotor.

9. A system according to claim 8, wherein switches are provided between the input rotor windings and the input rotor electromagnets to enable the polarity of the input rotor electromagnets to be changed.

10. A system according to any of claims 3 to 9, wherein the casing is formed in first and second parts and windings are provided on both parts of the casing.

11. A system according to claim 10, wherein switches are provided linking casing windings of the first and second parts, so that current flowing in windings of the second part may flow in either the same direction or the opposite direction to that of current in windings of the first part in accordance with a status of the switches.

12. A system according to claim 10 or 11 as dependent upon any of claims 6 to 9, wherein the first part surrounds the input rotor electromagnets and the second part surrounds the output rotor.

13. A system according to claim 12, wherein angular positioning of the first and second parts of the casing relative to one another is adjustable

14. A system according to claim 13, wherein the first and second parts are linked together by resilient biasing means and angular adjustment is provided automatically.

15. A system according to any of claims 3 to 14, wherein current induced in the input rotor is provided to the casing windings.

16. A system according to any of claims 3 to 15, wherein an external power source is provided for supplying at least part of the current requirements of the casing windings.

17. A system according to any of the claims 3 to 16, wherein the input rotor and casing are provided with three-phase windings.

18. A system according to any of claims 3 to 17, wherein the output rotor comprises one or more output rotor electromagnets.

19. A system according to claim 18, wherein a controllable current is supplied to the output rotor electromagnets from an external power source.

20. a system according to any of claims 3 to 18, wherein the output rotor comprises one or more permanent magnets.

21. A system according to any of the preceding claims, wherein a lock-up device is provided for synchronising output rotor speed with input rotor speed at a given gearing ratio.

22. A system according to any of the preceding claims, wherein a free-wheeling device is provided between input and output rotors to prevent output rotor speed from increasing above input rotor speed.

23. A system according to any one of the preceding claims, in which the casing surrounds the input and output rotors.

24. An electromagnetic transmission system comprising an input rotor having an input magnetic circuit, and output rotor having an output magnetic circuit and mounted concentrically with respect to the input rotor, and a casing having a number of windings surrounding the input and output rotors, wherein rotation of the input rotor at a given input rotor speed causes a corresponding rotation of the output rotor at an output rotor speed equivalent to the input rotor speed minus a slip speed.

25. A system substantially as described herein, with reference to the embodiments of Figures 1 and 2, or Figures 4 to 7 or Figures 8 and 9.

26. An infinitely variable automatic transmission comprising a system according to any of the preceding claims.

27. A vehicle incorporating an infinitely variable automatic transmission according to claim 26.

28. A vehicle according to claim 27, wherein the input rotor is connected to a vehicle motor and the output rotor is connected to one or more driving wheels of the vehicle.

29. A vehicle according to claim 28, wherein drive from the vehicle motor to the input rotor is disconnectable under certain conditions so as to enable the transmission, driven by the or each driving wheels, to be utilised as an electrical motor.

30. A vehicle according to any of claims 27 to 29, wherein electrical power is extractable from the transmission system to act as a vehicle brake.

31. A vehicle according to any of claims 27 to 30, wherein electrical power is extractable from the system to regenerate an energy storage device.

32. A vehicle substantially as herein described with reference to the accompanying drawings.

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Relevant Technical Fields (i) UK Cl (Ed.M) H2A (ii) Int Cl (Ed.5) H02K 16/02, 51/00 **Databases** (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii)	Application number GB 9409157.6 Search Examiner J COCKITT Date of completion of Search 29 JULY 1994 Documents considered relevant following a search in respect of Claims :- 1-28

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X	GB 2078016 A (P A MANAGEMENT) see whole document	1, 2, 24 at least
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X	GB 1063330 A (MAGNAVOX) see whole document eg Figure 5	1, 24 at least
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